3T intravascular MRI, IVUS and OCT: A study in contrast

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Audience: Interventional radiologists and clinicians interested in intravascular imaging.

Purpose: To compare, head-to-head, the performance of three intravascular (IV) imaging modalities—Ultrasound (IVUS), optical coherence tomography (OCT) and 3T MRI—for studying atherosclerotic and stented vessels. Atherosclerosis is marked by lesions which, with high extracellular lipid and thin fibrous caps are vulnerable to rupture. The disease is typically diagnosed by X-ray angiography, which reveals luminal narrowing but does not permit assessment of plaque vulnerability or early-stage vessel wall thickening. IVUS, OCT and MRI offer non-ionizing imaging alternatives. A 1:1 comparison is essential for evaluating the relative merits of what can and can't be seen with each modality.

Methods: We performed IVUS, OCT and 3T IVMRI on the *same* calcified human iliac specimens, and inside a Bard LifeStent XL 7mm nitinol stent in saline. For IVUS, we used a Volcano system at 10 frames/s, sensitivity/gain=1/63 and a 3.5F Eagle-Eye Gold IVUS imaging catheter inserted without X-ray. For OCT, we used a St. Jude Medical C7XR unit with a C7 Dragonfly IV imaging catheter without OCT flush, 100 frames/sec, pullback rate 2 cm/s. For MRI, we used a loopless antenna detectors[1] in a 3T Philips System, Multi-echo Gradient echo (GRE), TR=10ms, TE_1=4.7ms, ΔTE= 4.2ms, avg. of 5 echoes, FA = 35°, 200µm in-plane resolution, radial acquisition, Field of View (FoV) =20mm, T_{acq}=10s. For the stent image, MRI parameters were 2D GRE, 100µm in-plane resolution, TR/TE=100/7.8ms, T_{acq}= 20s, FA = 60°. MRI of the stented vessel was also done using the body coil with 2D GRE, in-plane resolution 1mm, TR/TE=500/1.8ms, FA=70°.

3T IVMRI, IVUS and OCT utilize intrinsically different imaging principles and contrast, confounding characterization by a single parameter: we investigated contrast- and signal-to-noise ratios (SNRs), effective FoV, speed, and artifacts.

Results and Discussions: IVUS is easy to operate, but produces images with low SNR, indistinct vessel wall demarcation, artifacts from calcification (Fig. 1a), and interference inside the stent (Fig 1e). OCT has the best spatial resolution but lacks penetration and FoV to show the extent of calcification (Fig. 1b). From inside, the stent is well demarcated for re-stenosis studies, with shadow artifacts on the outside (Fig. 1f). 3T IV MRI, although being the slowest, has superior soft-tissue contrast that demarcates both the extent of calcification and the vessel wall, as compared to the photograph (Fig. 1c, d). IV MRI offers much better visualization *inside* the stent compared to the body-coil MR image (Fig. 1 g, h). Its utility for studying stent re-stenosis is under investigation. Although IVUS vs. OCT[2] and IVUS vs. 1.5T IVMRI[3] have been studied earlier, as far as we are aware this is the first 1:1 comparison of all three modalities.

Conclusions: 3T IV MRI can characterize atherosclerosis in vessels and can offer imaging capability inside stented vessels with potentially significant advantages vs. existing methods.

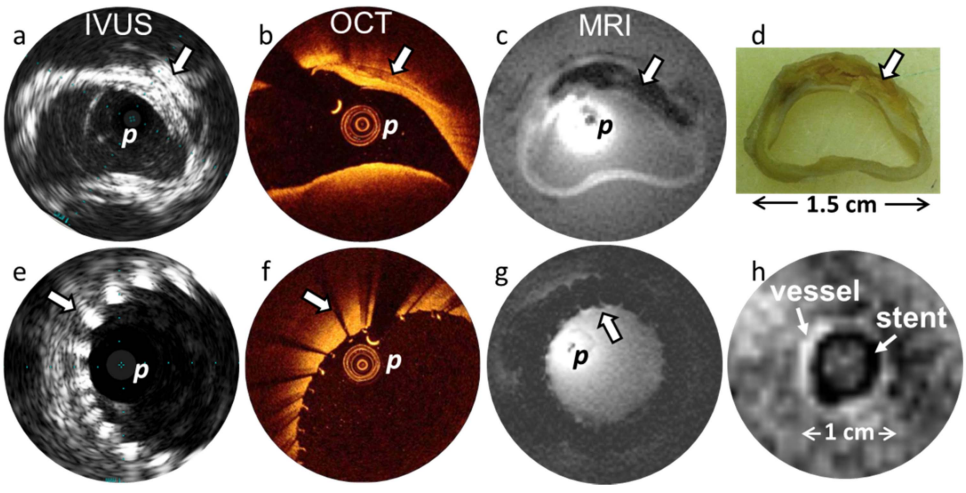

Figure 1: Human iliac artery specimen studied under **(a)** Intravascular Ultrasound (IVUS), **(b)** IV Optical coherence tomography (OCT) and **(c)** IV MRI. In-plane resolution=200µm **(d)** A photograph of the sectioned vessel. Arrow shows a calcified region and '*p*' marks the probe location in all images.

Vessel with a stent studied under **(e)** IVUS **(f)** IV OCT and **(g)** IV MRI, 100µm in-plane resolution. Arrow shows the stent in all images. **(h)** MRI of stented vessel using the body coil as receiver, in-plane resolution 1mm. '*p*' marks the probe location in all images.

References: [1] Ocali O, et. al., MRM 1997, 37:112–18 **[2]** Kubo et. al, Cardiovasc. Interv. & Ther. 2010, 25:2–10 **[3]** Larose E, et. al, Circulation 2005 112(15):2324-2331. *Supported by R01 HL090728. Thanks: Div. Cardiology (IVUS) and FDA Laurel (OCT).*